Aerosol Size Distribution and Composition from the Twin Otter during CRYSTAL-FACE

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Twin Otter & Relevant Instrumentation

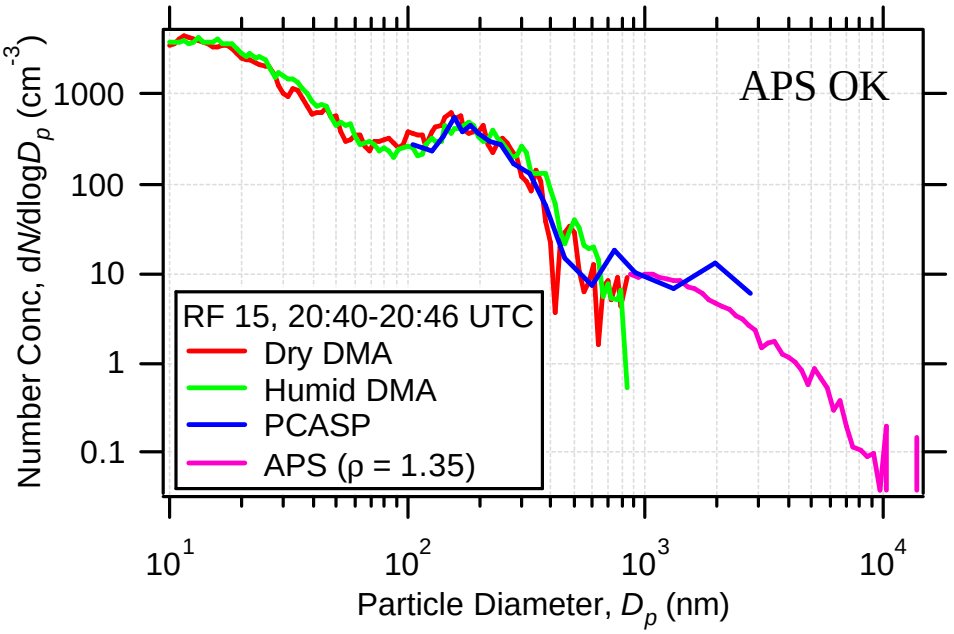
Twin Otter Goals:

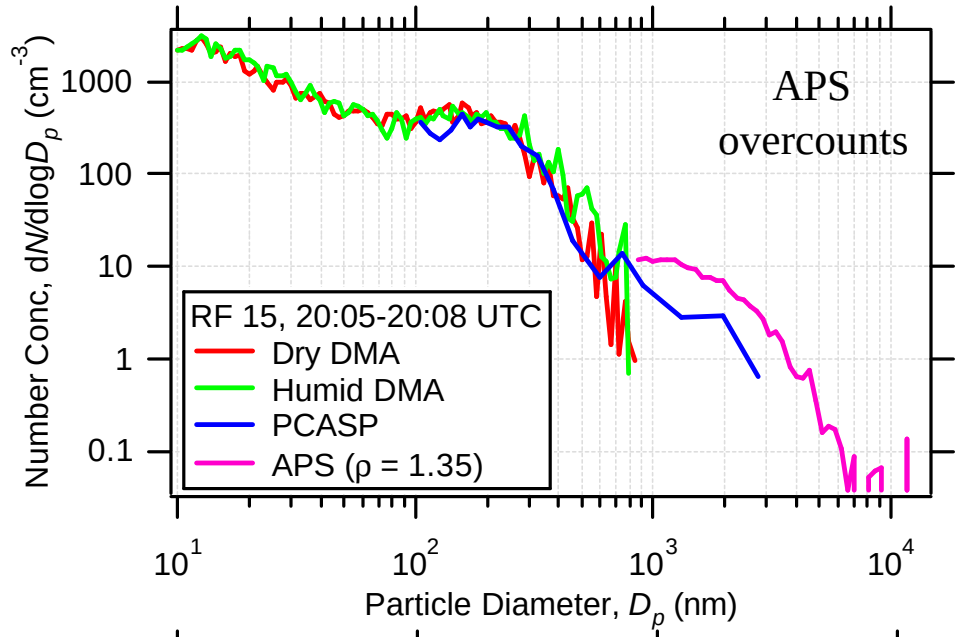
- To characterize aerosols in the boundary layer that are fed into convective systems, possibly participating in cirrus cloud formation
- To measure radiative fluxes under stratiform cirrus anvils.

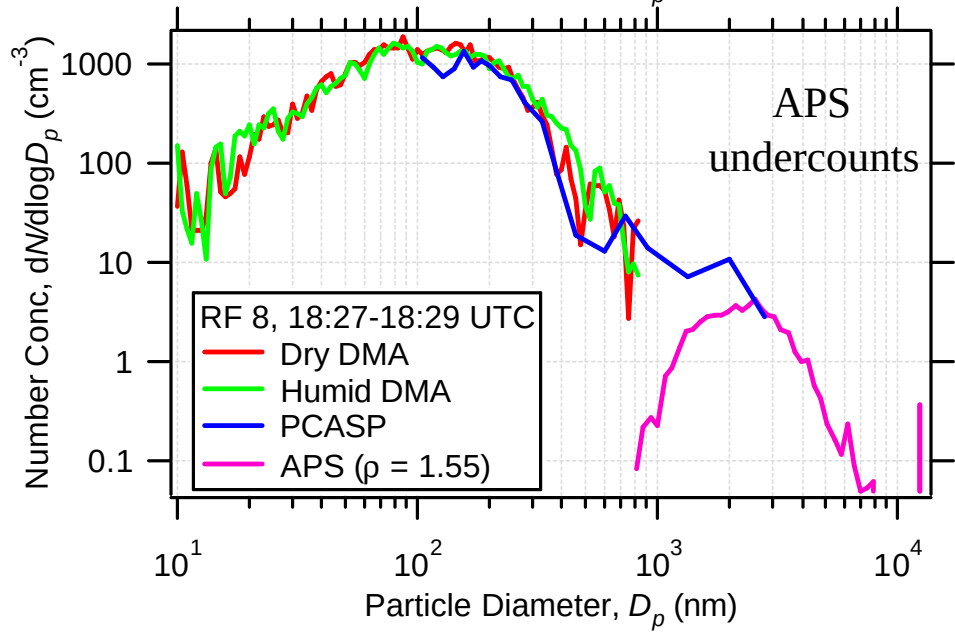
Instrumentation for Measuring Aerosol Size and Composition

Instrument	Aerosol Characterization	Time Response
Caltech Dual Automated Classified Aerosol Detectors DACAD) • 1 DMA at dry condition (~15% RH) • 1 DMA at humid condition (~70% RH)	• Size distribution (10-800 nm) at two relative humidities • Aerosol hygroscopicity	103 s
Aerodyne Aerosol Mass Spectrometer (AMS)	• Size-resolved (D_{va} = 40-1000 nm) aerosol composition of non-refractory species in time-of-flight mode • Integrated aerosol composition in mass spec mode	60 s
PMS Passive Cavity Aerosol Spectrometer Probe (PCASP-100X)	• Size distribution (0.1-3 μm)	1 s
TSI Aerodynamic Particle Sizer (APS)	• Size distribution (0.8-20 μm)	25 s

Agreement of Measured Size Distributions

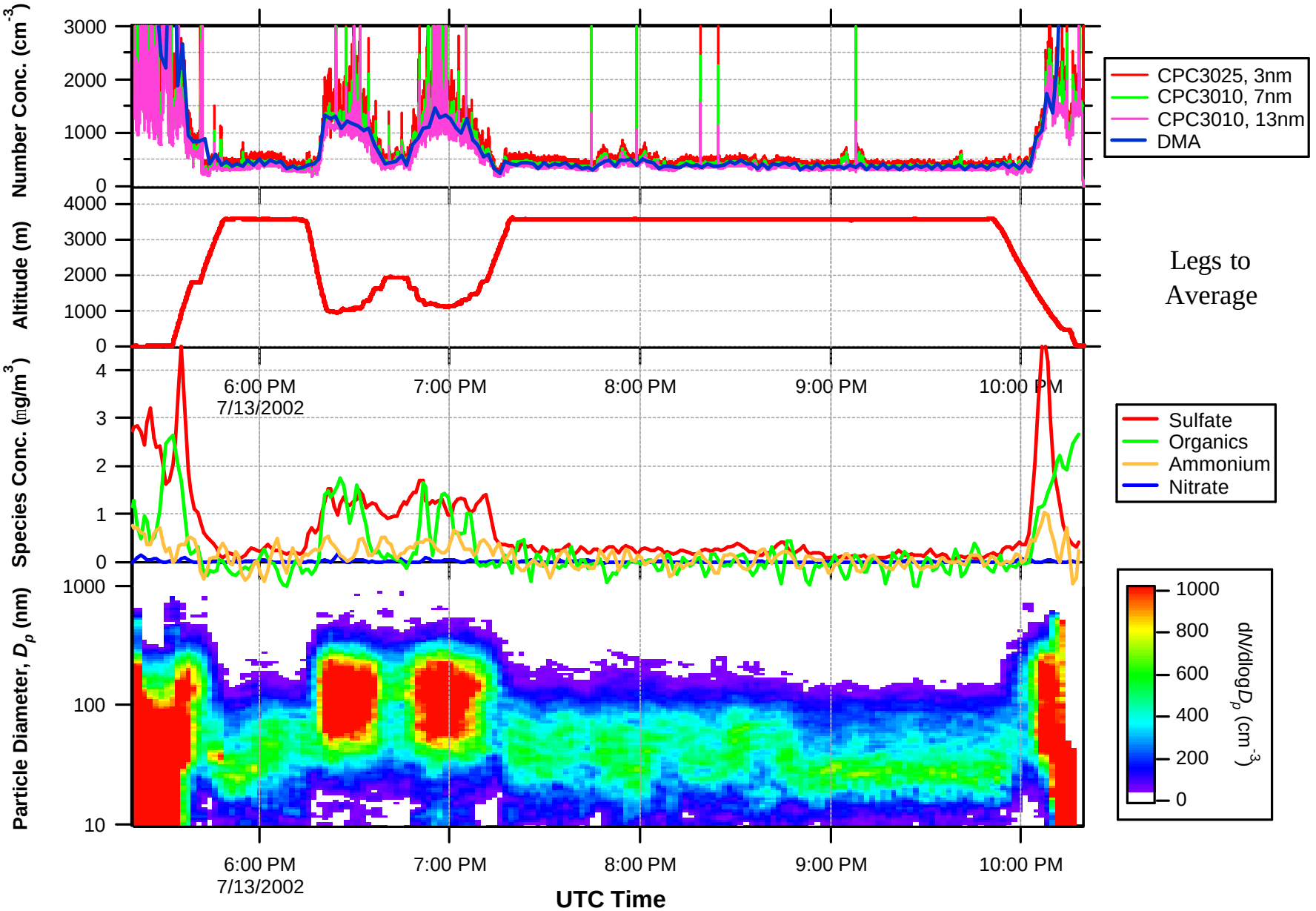






- The overlapping region between the DMA and PCASP (0.1-0.7 μm) shows good agreement between the two distributions (dN/dlogD_p within a factor of two of each other at a given size).
- The overlapping region between the PCASP and APS (0.8-3 μm) suggests that the APS often either undercounts or overcounts, but the APS size distribution appears to be reasonable at larger sizes. A super-micron mode is usually not apparent in either measurement.
- The conversion from APS D_a to D_p uses a density estimated from the AMS composition

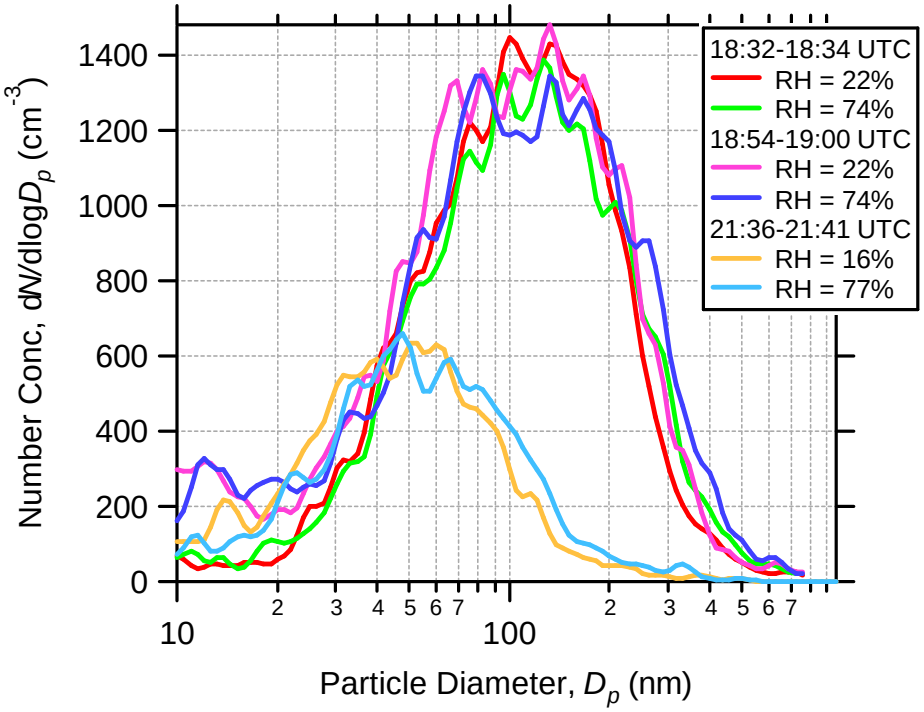
RF 8, 7/13/02 : Typical Aerosol



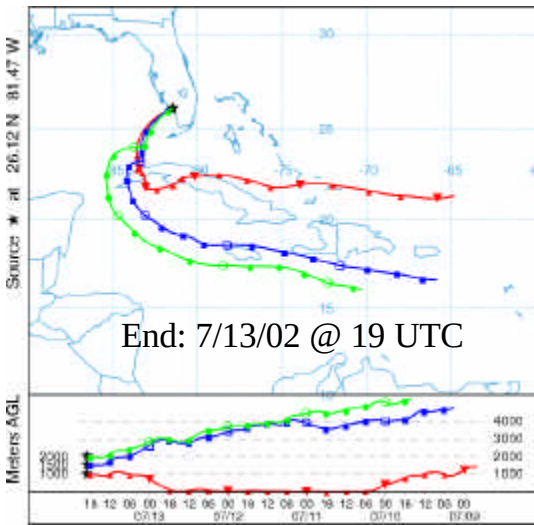
RF 8, 7/13/02 : Typical Aerosol

Characteristics of typical aerosol encountered during CRYSTAL-FACE:

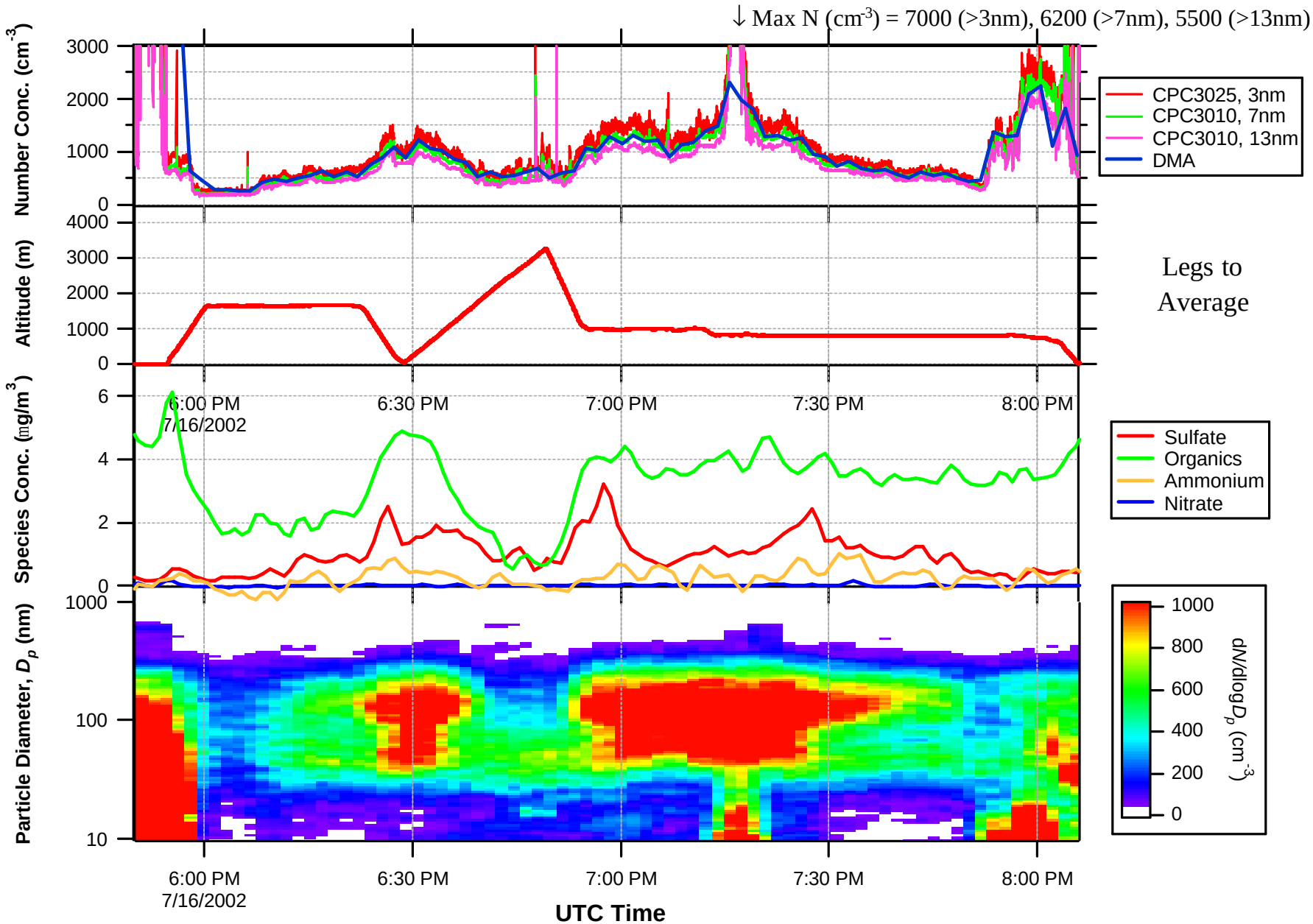
- Low number concentration (< 2000 cm^{-3}), relatively homogeneous in number and size distribution within each altitude
- Aerosol composition is primarily sulfate and organics, in roughly 1:1 ratio by mass
- Size distributions show either a weak bimodal shape with a minimum at about 100 nm, or a flat peak at 60-180 nm
- Aerosols at altitudes above 3000 m have small modes between 30-50 nm
- Back trajectory shows marine origin



RF	UTC Time	Alt (m)	Humid Mode D_p (nm)	Size Distrib. Remarks	Number Conc. (cm^{-3})	SO_4^{2+} mass ($\mu g/m^3$)	Organics mass ($\mu g/m^3$)	Org / SO_4	Calc. Density (g/cm^3)
8	18:32-18:34	1267	~ 120	Unimodal	1058	1.31	0.78	0.6	1.51
8	18:54-19:00	1137	~130	Unimodal	1330	1.16	0.99	0.85	1.44
8	20:27-20:32	3556	50	Unimodal	453	0.34	< DL	< DL	N/A
8	21:36-21:41	3557	32	Unimodal	384	0.08	< DL	< DL	N/A

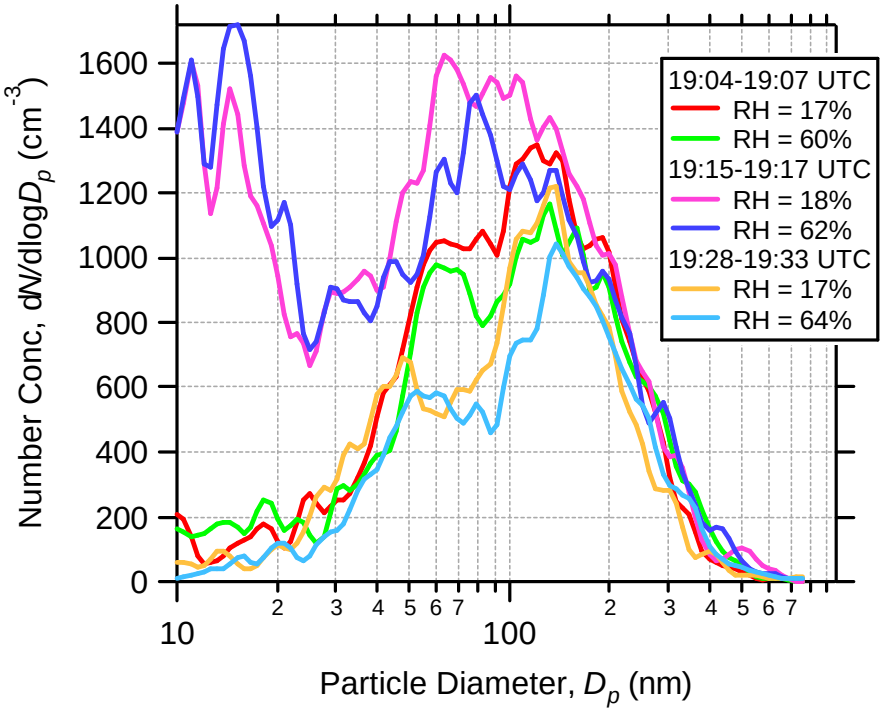


RF 9, 7/16/02 : High-Organics Aerosol



RF 9, 7/16/02 : High-Organics Aerosol

- On 7/16 and 7/18 (RF 9,10,11), the aerosol is largely composed of organic species
- Total number concentration is not significantly elevated over the normal range except for a few spikes in ultrafine aerosol
- AMS sulfate and organic size distributions are similar for D_p between 250 and 500 nm, indicating internally-mixed aerosol in this range
- Back trajectories show influence of continental emissions during the last day of aerosol history



* Total number from CPC 3025 (because of high number of ultrafine aerosol)

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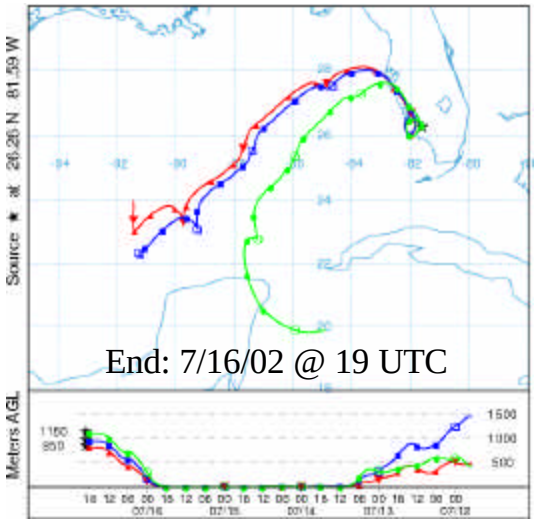
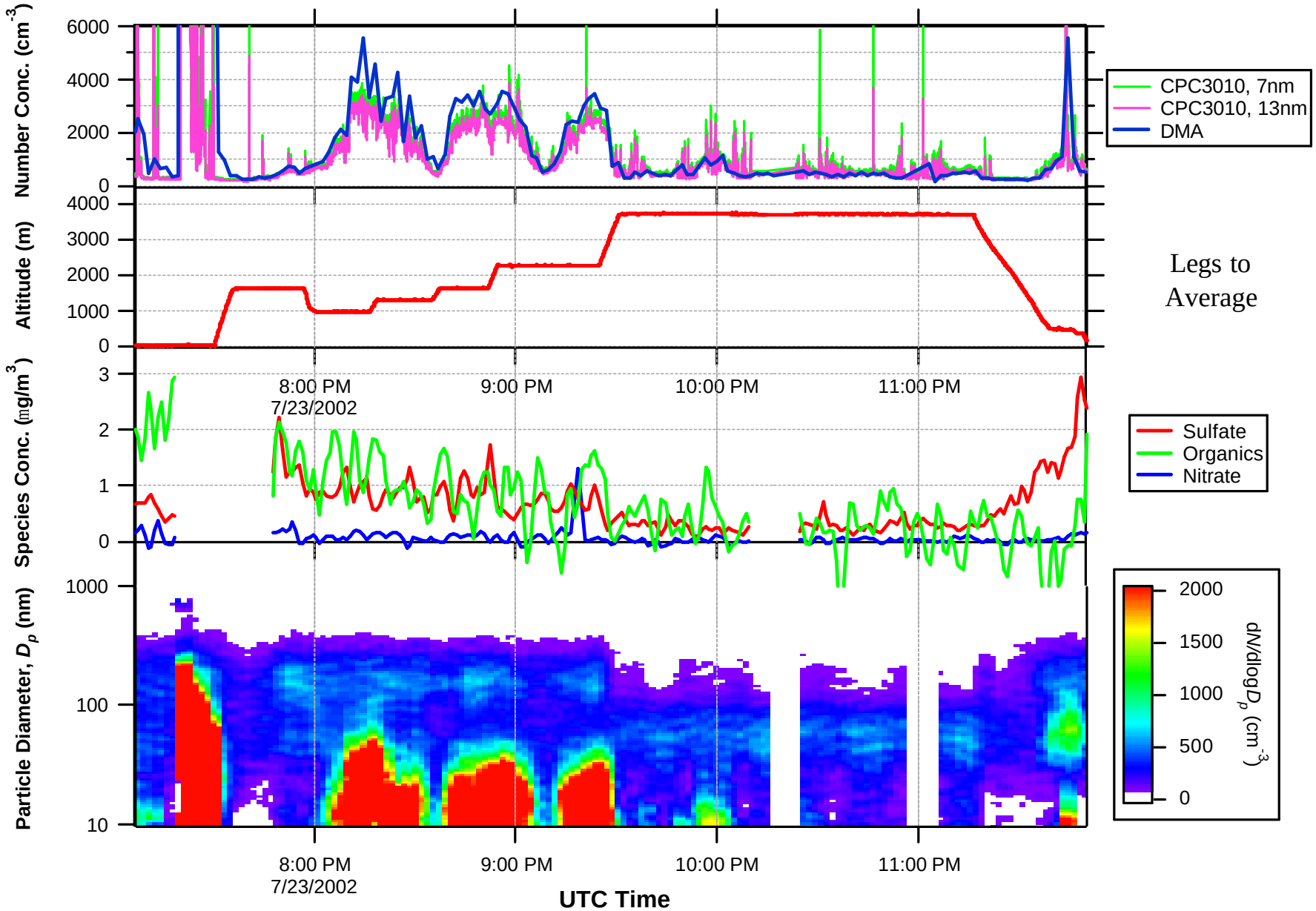
9	19:04-19:07	975	65 & 130	Bimodal	1063	0.71	3.54	4.99	1.09
9	19:15-19:17	824	15 & 80	Bimodal	3732*	1.04	3.94	3.79	1.13
9	19:28-19:33	803	60 & 140	Bimodal	815	1.43	3.76	2.63	1.20
10	16:13-16:16	707	30 & 125	Bimodal	7985	2.25	7.83	3.48	1.15
10	16:20-16:21	766	22 & 120	Bimodal	17024	2.7	8.33	3.09	1.17

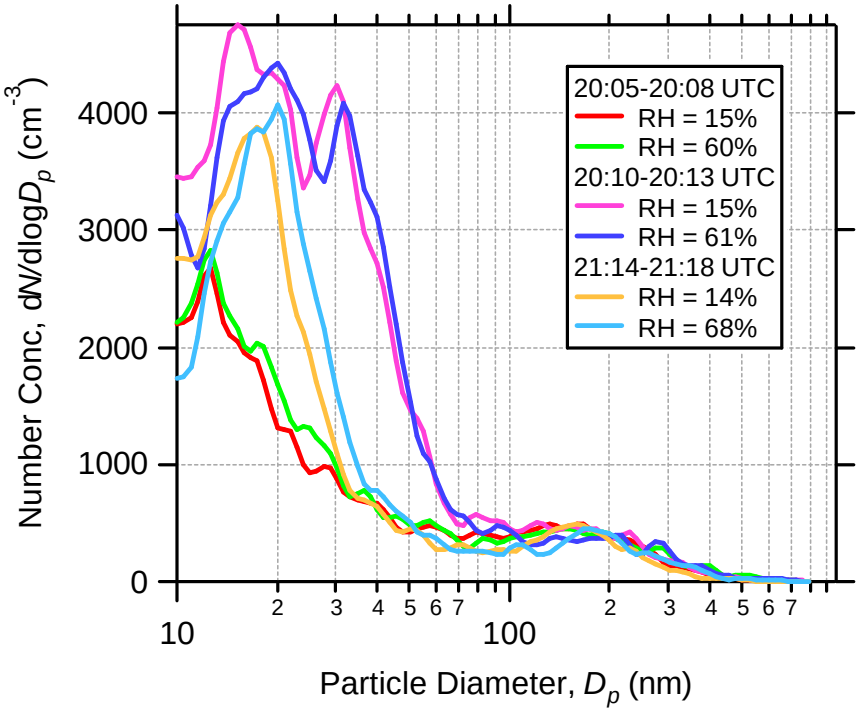


RF 15, 7/23/02 : Fine Aerosol



RF 15, 7/23/02 : Fine Aerosol

- 7/23 is marked by high concentrations of small nuclei-mode particles below 50 nm, which were observed during cloud-probing at altitudes below 2300 m
- Aerosol profile is also inhomogeneous within an altitude layer.
- Slightly elevated mass ratios of organics to sulfate
- Back trajectory indicates marine origin which could implicate relatively freshly-nucleated natural particles



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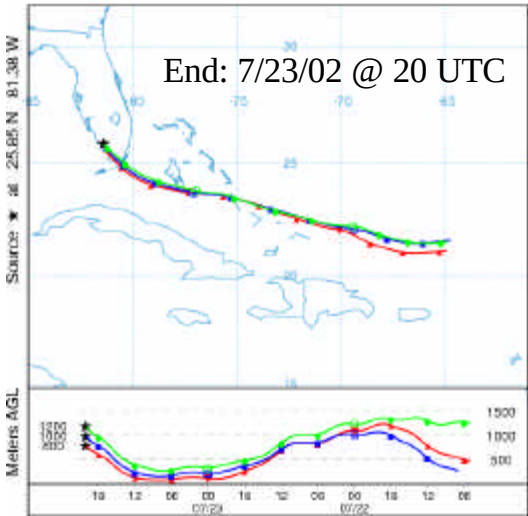
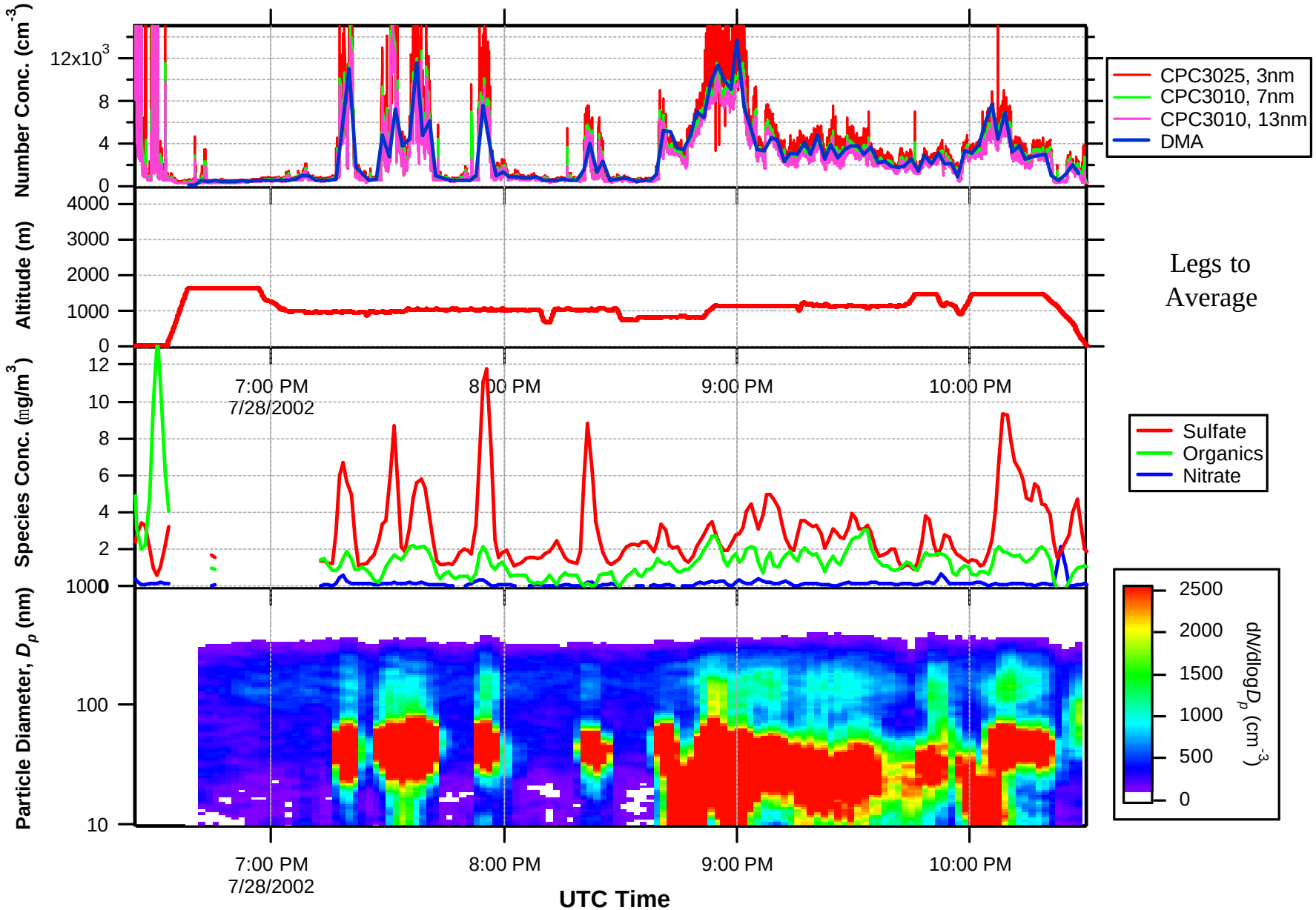
15	20:05:20-08	971	13 & 150	Bimodal w/ ultrafine	1974	0.79	2.1	0.73	1.20
15	20:10-20:13	971	20 & 30	Fine modes dominate	4008	0.88	1.61	0.65	1.27
15	21:14-21:18	2245	20 & 170	Bimodal sharp peak	3332	1.11	1.31	0.54	1.37

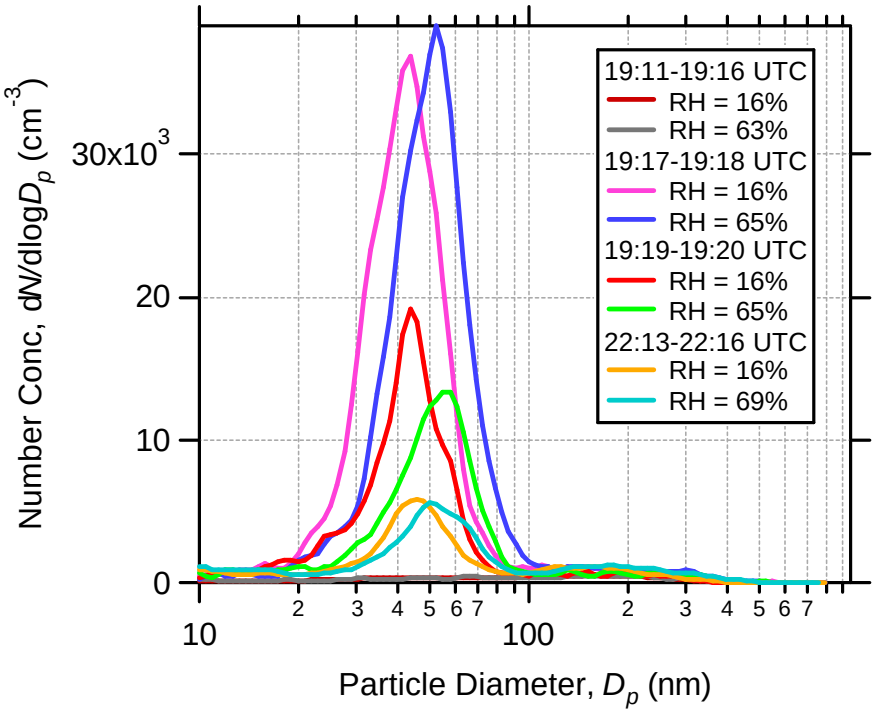


RF 18, 7/28/02 : Non-homogeneous Air Mass



RF 18, 7/28/02 : Non-homogeneous Air Mass

- 7/28 is marked by uncommonly inhomogeneous air mass, characterized by frequent spikes in number concentration, mainly of nuclei-mode and ultrafine aerosol, even at a constant altitude
- Inhomogeneity indicates on-going mixing process. This is counter-intuitive because back trajectories show a very homogeneous history of the air mass, both in terms of altitude and insensitivity to model start time.
- The inhomogeneity may be due to the entrainment or formation of fresh particles in close proximity to the sampling location
- The time scale of change in the number concentration is sometimes too fast for a DMA scan to completely capture the time variation in size distribution.



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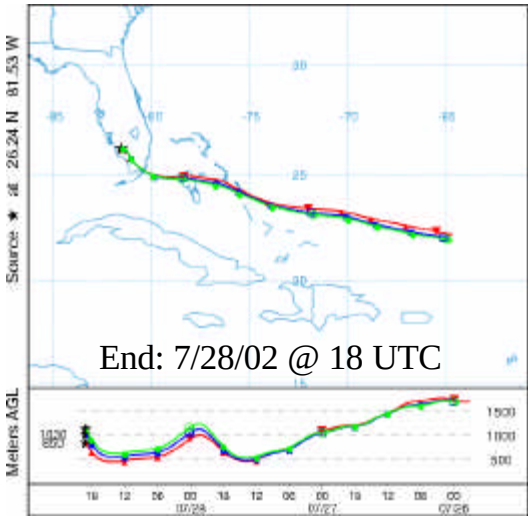
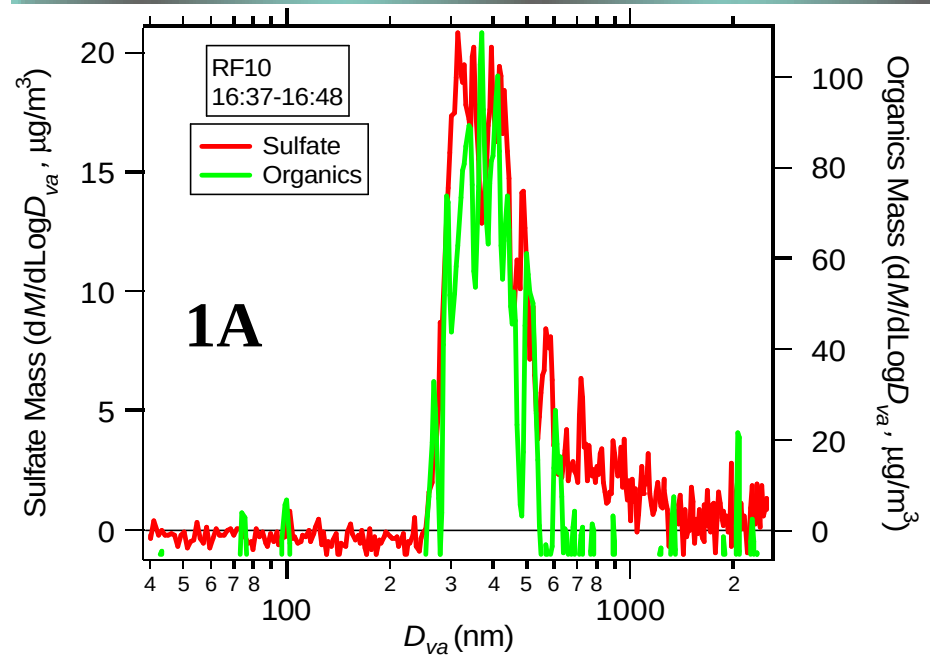
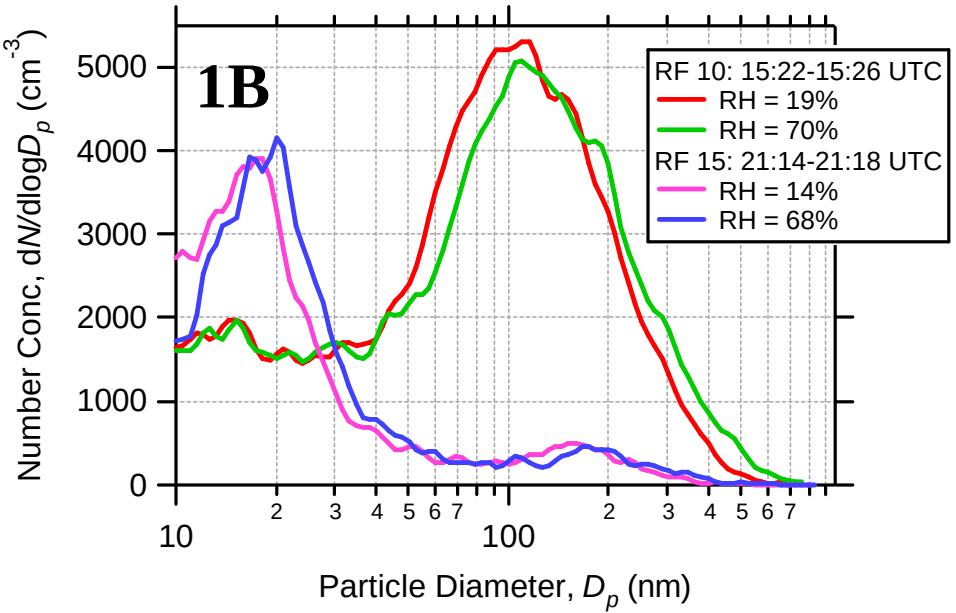
18	19:11-19:16	958	~65 & 170	weakly bimodal	588	1.38	1.22	0.88	1.43
18	19:17-19:18	964	52	Fine peak growing	4461	7.6	1.17	0.15	1.68
18	19:19-19:20	975	55	Fine peak dominates	11222	5.58	1.88	0.34	1.6
18	22:13-22:16	1466	50 & 180	Bimodal	2808	5.22	1.31	0.25	1.64



General Observations



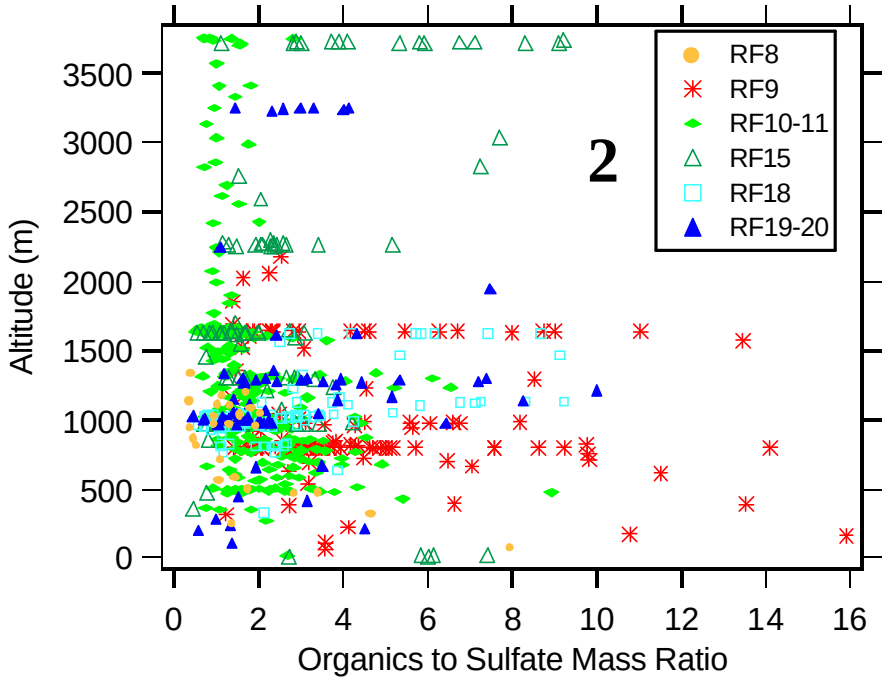


1. Evidence of internal mixing

A. AMS: Similar mass distributions of sulfate and organics, at least for the D_p range of 250-500 nm

B. DMA: Similar growth of particles below 500 nm when exposed to the same RH (note that number concentrations above 500 nm are small; thus, hygroscopic growth becomes difficult to determine)

2. Higher organic-to-sulfate mass ratios are generally found at lower altitudes, with the exception of RF 15



Summary & Acknowledgements

Summary:

- Various types of air masses were sampled in the Twin Otter flights
- The time scale of change in the aerosol number concentration depends on the size of interest: the fine nuclei mode aerosol (D_p < 100 nm) varies with a much shorter time scale than that of the accumulation mode (D_p > 100 nm). Spikes of high aerosol number often occur in the ultrafine size range.
- Above the altitude of ~ 3000 m, particles becomes sparse and are generally uniform in number and size, with a mode between 30-50 nm
- Aerosol below 500 nm is predominantly internally-mixed, as evidenced by:
  - Composition that is generally uniform with size
  - Similar growth behavior with RH

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- James Allan (UMIST, AMS Analysis Software)
- NOAA Air Resources Laboratory (ARL) for provision of the HYSPLIT transport and dispersion model